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RADIOFREQUENCY RADIATION:
Activities and Issues

by

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16. ABSTRACT

The question of human safety relative to exposure to RF radiation obviously predates the first ANSI guideline established in 1966, but no enforceable Federal standards or guidelines exist for RF radiation exposure; the ANSI guideline which was revised in 1982 is voluntary or advisory. EPA has been pursuing the goal of promulgating guidance to control exposure of the public to RF radiation. In support of this regulatory activity, a report entitled "Biological Effects of Radiofrequency Radiation" was published in September 1984. The conclusion of the report was that biological effects occurred at a dose rate of about 1 W/kg, and that these effects may be significant under certain environmental conditions. Examples of adverse biological effects that occur in laboratory animals at dose rates of 2-6 W/kg are death and temporary male sterility. These effects as well as the behavioral changes that are the basis for the ANSI guideline can be attributed to heat stress in animals caused by absorption of RF energy. Some experimental results occur at very low exposure conditions that cause no significant thermal input; these responses are called non-thermal effects. The mechanisms of interaction of non-thermal effects and their physiological significance are a subject of scientific debate. RF radiation research budget reductions, which reflect changes in funding priorities, will leave unresolved many of the questions concerning the biological effects of RF radiation and their possible health implications.

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RADIOFREQUENCY RADIATION: ACTIVITIES AND ISSUES

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The following topics are discussed in this report: 1) environmental exposure levels of radiofrequency (RF) radiation; 2) Federal and other activities related to the control of exposure of the general public to RF radiation; 3) biological effects; 4) limitations in our knowledge of biological effects; and 5) research support.

RF radiation is nonionizing electromagnetic energy at frequencies greater than zero to 3×10^{12} Hertz (Hz or cycles per second). Radiofrequencies from 3×10^{8} to 3×10^{11} Hz (300 MHz to 300 GHz) are called microwaves. Examples of environmental sources of RF radiation are radio and television broadcast antennas, radar antennas, satellite communication facilities, mobile and hand-held radio transmitters, and cellular telephone systems. The RF spectrum includes 60 Hz, the frequency of the electrical power transmission system in the U.S., but this report is limited to higher frequencies, namely, 500 kHz to 100 GHz, that are generated by sources such as those listed above.

1. Environmental exposure levels. As a result of its environmental monitoring activity, EPA has concluded that over 99% of the U.S. population is exposed continuously to RF radiation, mainly from radio and television broadcast frequencies, at levels not greater than 0.001 mW/cm^2 (Tell and Mantiply 1980). This level is 1,000 times lower than the most restrictive (1 mW/cm^2) exposure limit recommended by the American National Standards Institute (ANSI) for the frequency range of 30-300 MHz (ANSI 1982). Nevertheless, there are some particularly significant sources of population exposure. Exposures from broadcast sources can exceed 5 mW/cm^2 near densely grouped antenna systems, and levels of 0.1 mW/cm^2 may exist in high-rise buildings adjoining FM radio or TV antennas (Tell and O'Brien 1977; Tell and Hankin 1978). Physiological effects occur in experimental animals exposed to intensities that exist in the environment, although these intensities may not be typical environmental exposures (Elder and Cahill 1984).

2. Federal and other exposure control activities. The question of human safety relative to exposure to RF radiation obviously predates the first ANSI guideline established in 1966. In 1974 this guideline was reaffirmed, but ANSI decided to revise its recommendation in February 1979 based on a review of the literature on RF radiation. This revision, which was published in 1982, is based on the conclusion that reliable evidence of hazardous

effects is associated with whole-body average dose rates (specific absorption rates, SAR) greater than 4 W/kg. A safety factor of 10 was adopted so that the revised guideline restricts exposure to one-tenth of the hazardous effect level, that is, 0.4 W/kg. The limits expressed in power density are equal to or greater than 1 mW/cm^2. The 1982 recommendations are frequency specific because exposure limits vary in each of five regions spanning the frequency range of 300 kHz to 100 GHz (ANSI 1982). In contrast, the 1974 guideline was 10 mW/cm^2 for all frequencies from 10 MHz to 100 GHz.

No enforceable Federal standards or guidelines exist for RF radiation exposure of the public or workers; the ANSI guideline is voluntary or advisory. In the absence of Federal regulation, a number of cities and states have adopted standards with different exposure limits. For example, Connecticut has adopted a standard based on the same dose rate (0.4 W/kg) as the ANSI guideline. In the neighboring state of Massachusetts, a standard five times more stringent was adopted. Multnomah County, Oregon, approved a standard similar to the one in Massachusetts. New York City has a standard of 0.02 W/kg.

At the Federal level, EPA has been pursuing the goal of promulgating guidance to control exposure of the public to RF radiation. In support of this regulatory activity, a report entitled "Biological Effects of Radiofrequency Radiation" was published in September 1984. The conclusion of the report was that biological effects occurred at a dose rate of about 1 W/kg, and that these effects may be significant under certain environmental conditions (Elder and Cahill 1984). This document was reviewed by a committee of the Agency's Science Advisory Board who concluded that the document could serve as a scientifically defensible basis for the development of radiation protection guidelines.

Other national and international organizations have prepared reports that will be available in the near future on RF radiation safety and related issues. Four of these reports are mentioned here. The National Council on Radiation Protection and Measurements (NCRP) has written a document entitled "Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields." As the title implies, the report contains a review of the literature on biological effects and recommendations for exposure limits. This report will be published in 1986 (NCRP 1986).

A draft report on RF radiation that will be a chapter in the World Health Organization revised series on nonionizing radiation protection (see WHO 1982) has recently been completed. The final draft is expected in the summer of 1986. The report includes a discussion of the following topics: quantities and units, exposure sources and devices, instrumentation and measurements, dosimetry, biological effects, and protective measures and standards.

With regard to workers, the National Institute for Occupational Safety and Health has prepared a draft review document entitled "The Recommended Occupational Exposure Standard for Radiofrequency Radiation" (May 1985). This document includes a discussion of biological effects and a very extensive table of the literature on this subject (NIOSH 1985).

The Committee on Interagency Radiation Research and Policy Coordination (CIRRPC) was established in April 1984 by the Office of Science and Technology Policy. The purpose of CIRRPC is to (1) coordinate radiation matters between Federal agencies, (2) evaluate radiation research, and (3) advise the Office of Science and Technology Policy on radiation policy issues. The primary emphasis of CIRRPC is ionizing radiation issues, but there is some interest in nonionizing RF radiation. The CIRRPC science panel asked the member Federal agencies to respond to a questionnaire concerning the most important radiation issues. The panel also sent the questionnaire to the chairmen of appropriate Congressional committees and members of Congress. Nonionizing radiation was one of the ten radiation issues identified as most important. In addition, the CIRRPC science panel is preparing a report on the research needs in RF radiation that is due in early 1986 (Adey et al. 1986).

3. Biological effects. The literature contains reports of significant adverse biological effects in laboratory animals at dose rates of 2-6 W/kg. For example, (1) death of rats and dogs has occurred at exposures of 4-6 W/kg (Berman et al. 1985, Michaelson et al. 1961) and (2) temporary sterility has been produced in the male rat at 5.6 W/kg (Berman et al. 1980). These effects as well as the behavioral changes that are the basis for the ANSI guideline can be attributed to heat stress in animals caused by absorption of RF energy. In fact, severe heat stress symptoms have been observed in the dog, rabbit, and monkey at dose rates of 2-4 W/kg (Michaelson et al. 1961, Wangemann and Cleary 1976, Lotz 1985).

The biological effects mentioned above were observed in experiments done at normal laboratory conditions of temperature and humidity. Since the effects were due to heat stress, it is logical to conclude that the same effects will occur at lower dose rates under more adverse conditions of temperature and humidity (Gage 1979). This reasoning formed part of the basis for the conclusion in the EPA report, i.e., "biological effects occur at an SAR of about 1 W/Kg; some of them may be significant under certain environmental conditions." The consideration of heat stress addresses the issue of heat wave episodes that may occur in some parts of the U.S. during summer months and the probable synergistic action of such extremely adverse conditions and exposure to RF radiation (Elder and Cahill 1984).

In general, the thermal effects of RF exposure have been documented in laboratory animals that have fur, do not sweat, and therefore have thermoregulatory systems quite different from human beings. Hence, this is one of the problems in the extrapolation of thermal responses in irradiated laboratory animals to human beings. Furthermore, our knowledge of how the human body regulates the thermal input from RF radiation is quite limited. The similarities and differences in thermoregulatory responses to RF radiation exposure, fever episodes, and exercise are the subject of scientific debate at this time. For example, bicycle exercise can increase the body's metabolic rate from the normal value of about 1 W/kg to more than 4 W/kg, perhaps up to 7-10 W/kg (Chappuis et al. 1976). Body temperature may increase, but the thermal regulatory system controls the temperature within normal limits, particularly in a healthy individual. For comparison, note that the 1982 ANSI recommendation for RF radiation exposure sets the limit at 0.4 W/kg.

One may consider three types of biological effects due to RF radiation: thermal effects (discussed above), athermal effects, and non-thermal effects. Athermal effects comprise a less obvious but important response category. These effects may be described as physiological changes in animals in which the exposure, usually 0.1 - 1.0 W/kg, caused no increase in body core temperature. These dose rates can result in sufficient absorption of RF energy to activate one or more of the thermal regulatory receptors in the body and thus cause a physiological response. However, the thermal input is small and the animal is able to maintain normal core temperature. Some of the effects can be duplicated by administration of glucocorticoids, chemical substances that appear in the blood stream in response to heat stress and other stressful stimuli (Smialowicz 1984, Liddle and Blackman 1984).

Some experimental results, especially in vitro results, occur at very low exposure conditions that cause no significant thermal input and thus no significant change in temperature; these responses are called non-thermal effects. Non-thermal effects reported in the literature include changes in the EEG (Takashima et al. 1979), effects on cellular membrane potentials (Arber and Lin 1985, Seaman and Wachtel 1978) and ion transport (Cleary et al. 1982, Fisher et al. 1982, Liburdy and Penn 1984), DNA resonant absorption (Swicord et al. 1983) and effects on brain calcium ion efflux (Bawin et al. 1975, Blackman et al. 1985). The mechanisms of interaction of non-thermal effects, their physiological significance, and the related question of how non-thermal effects should be involved in the development of RF radiation exposure guidelines are a subject of debate by the scientific community at the present time. Frequently, the distinction between athermal and non-thermal effects becomes unclear. Only an understanding of the mechanism of action will allow one to make a determination of the type of response and this information is important for extrapolation of effects in animals and other systems to potential consequences in human beings.

4. Limitations in bio-effects database. The current literature is quite limited with respect to frequency range. There is very little information on RF effects in human beings and limited data on responses of animals at frequencies above 10 GHz or below 10 MHz. In fact, most animal experiments were done at two frequencies, namely 915 and 2450 MHz. Thus, current guidelines and standards for broad frequency ranges such as 300 kHz to 100 GHz are based largely on biological effects at relatively few frequencies.

Another limitation of the literature is the undetermined thresholds for most biological effects. There are many reports of effects, but most of the papers just document effects that occurred at one or a few exposure levels, and do not provide dose-response relationships. Threshold exposure levels for most biological effects remain unknown. They are important in risk assessment because they define the lowest effective exposure level for biological effects.

Other limitations include use of plane-wave exposures in the laboratory whereas realistic environmental exposures are much more complex due to multiple frequencies and modulations of the waveforms. Additional factors that may be mentioned include frequency-specific absorption, localized energy absorption, and the rate of energy absorption. In comparison to conventional heating sources, RF energy is uniquely capable of depositing energy in the human body. One application of the ability of RF radiation to penetrate deeply into body tissues and to heat tissue is medical diathermy. Another example of the unique way RF energy can be absorbed is the phenomenon known as "RF hearing," an auditory effect, by which some human beings perceive radiation from a radar source (a pulsed RF source) as a buzz, click, or hum in the back of their head. Although one pulse may be sufficient to evoke a response, the incident direction cannot be discerned. The pulse of energy is absorbed in some part of the brain or head, and a very brief thermoelastic expansion occurs in the tissue or fluid. Collapse of the expanded volume sends a pressure wave through the head that is perceived by the ear as sound through normal acoustic hearing mechanisms (Elder 1984).

5. Research Support. Resources for RF radiation research have diminished quite dramatically in recent years. A letter written in March 1985 by Don R. Justesen, former president of the Bioelectromagnetic Society, entitled "Averting the Death of a Discipline," summarizes recent budget actions that affect RF radiation research (Justesen 1985). The letter begins: "As president of the Bioelectromagnetic Society, I feel keenly the responsibility of looking after the interests of the rather new discipline, which was scattered and segmented before its organizational birth in the Bioelectromagnetic Society. Several agencies of the U.S. government and other sponsors have recently proposed reduction of support for, or the outright shutdown of research programs that fall within the perimeter of the Bioelectromagnetic Society . . . ." The letter lists nine impacts of budget reductions; five of them are given below.

- The EPA research program in Research Triangle Park, North Carolina on RF radiation health effects has been scheduled for complete inactivation.

- The U.S. Department of the Navy has inactivated its RF radiation bioeffects program at the Naval Medical Research Institute in Bethesda, MD.

- Navy support of biological research at its facility in Pensacola has also been markedly reduced.

- Extramural funding for biological effects of RF radiation by the Naval Medical Research and Development Command has been reduced to zero.

- Extramural funding of RF radiation research has been reduced to an almost nonexistent level by the National Science Foundation, the National Institutes of Health, and the Food and Drug Administration.

The remaining budget impacts that were addressed in the letter were mainly relevant to the decline in support for research at 60 Hz, the frequency of electric power transmission lines. It is concluded that the outlook for RF radiation research support is bleak. The budget reductions, which reflect changes in funding priorities, will leave unresolved many of the questions concerning the biological effects of RF radiation and their possible health implications.

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